

Flavor Physics and CP Violation at High Energy

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CPM FNAL, Oct 12th 2012

Flavor and CP Viol' @ HEF???

- We have two particles whose flavor and CP properties still need thorough investigation:
 - top quark
 - the new 125GeV particle, the “Higgs”
- Any other particle discussed in the New Particles subgroup needs to undergo the same study

Top

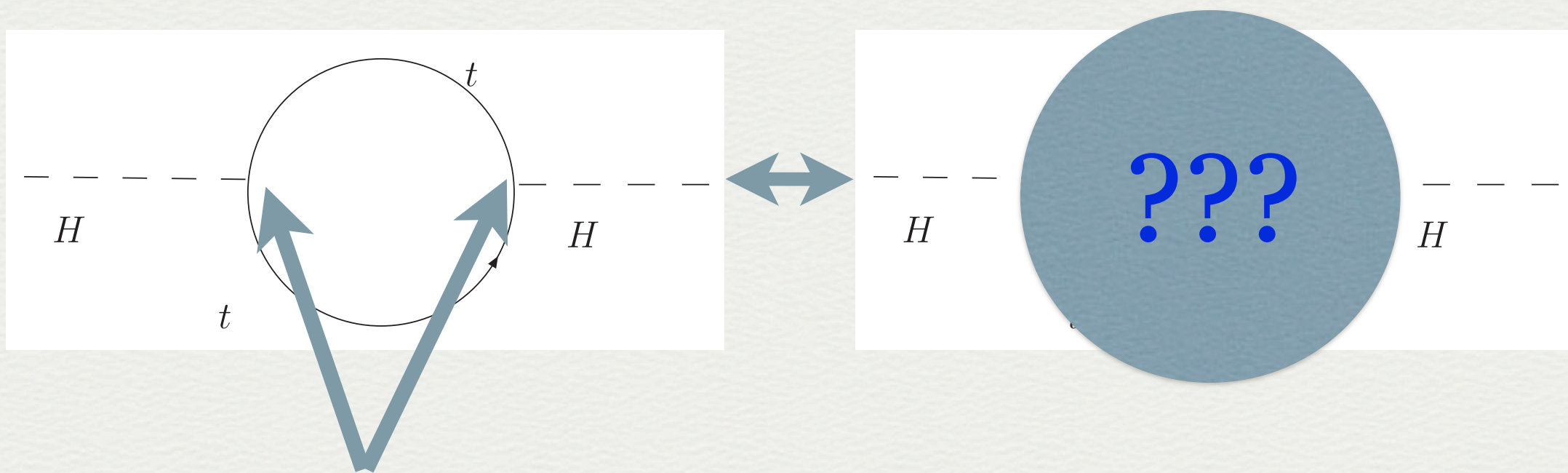
- top quark (synergy with the top quark working group)
- interesting region for FCNCs ($t \rightarrow (c,u) + (Z,\gamma,g)$) is mostly with BR's below 10^{-4}
- single top production via FCNC's
- CP violation (T viol') interactions only constrained indirectly via loops (EDMs, down-sector flavor viol'..)
- CP viol' using triple product decays?
- Footprint of an interesting flavor story in other observables? (A_{fb} docet...)
- Indirect constraints from low energy observables \rightarrow synergy with Intensity Frontier groups

Higgs

- Flavor (both quark and lepton) and CP viol' in the Higgs sector (synergy with the Higgs working group)
- need to look for **flavor non-universality** (**beyond the Yukawa**) and flavor violation in decays
- if an extended Higgs sector is found this applies for all the Higgs states
- a **CP violating extended Higgs** sector may be relevant for models of **EW scale baryogenesis** (synergy with Cosmology Frontier)

Flavor Viol' with new particles?

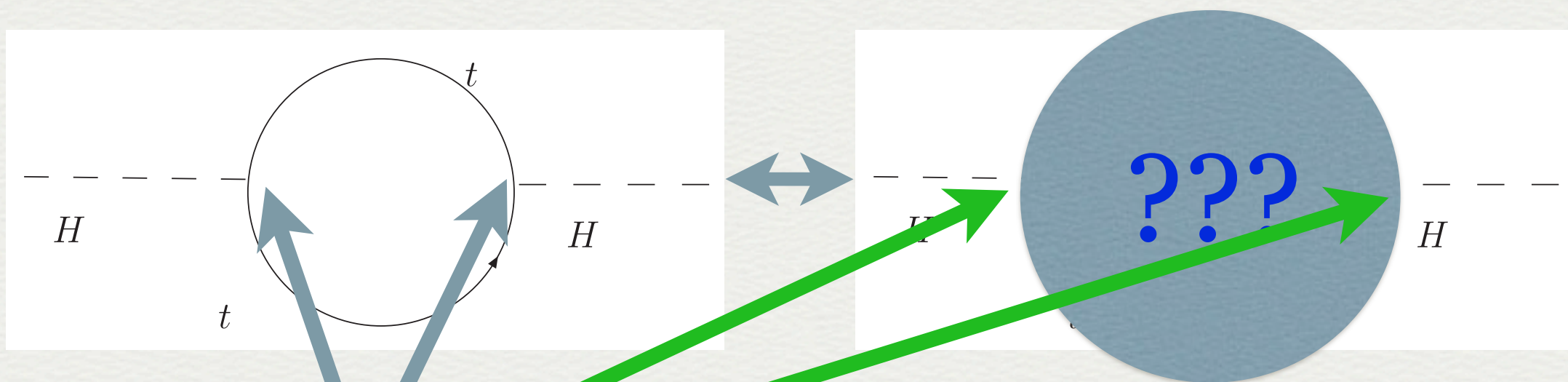
- Discovery of new particles do not guarantee an interesting flavor story, but:



largest eigenvalue of Y_u

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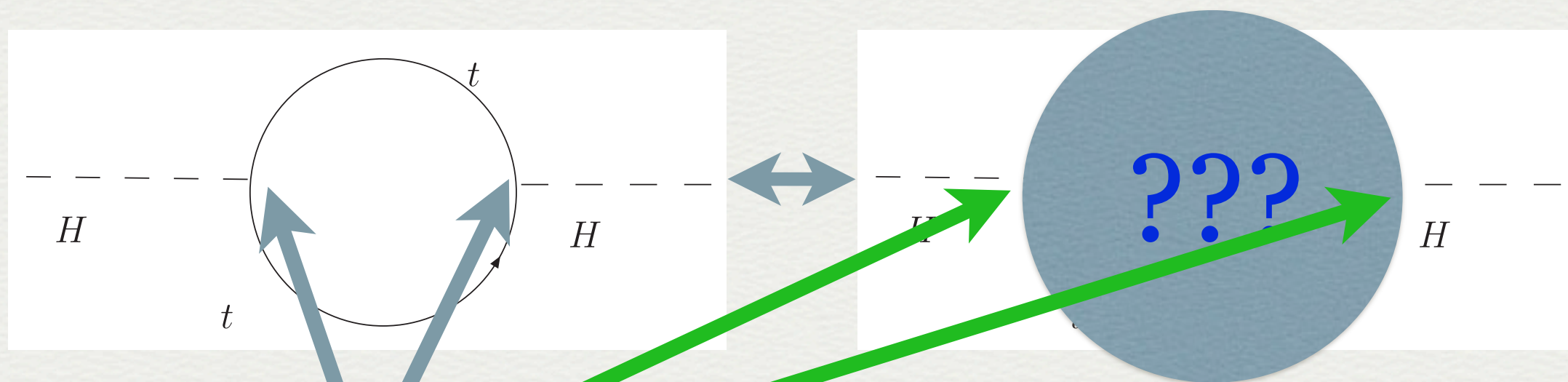


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At least we expect some non-trivial flavor structure for the New Physics (as much as we expect NP at the TeV scale...)

Flavor Viol' with new particles?

- If the origin of the Yukawa couplings is around the TeV scale (e.g. as in some Randall-Sundrum models) you expect
 - new particles that “know” the Yukawa couplings (need something to distinguish “big” numbers and “small” numbers)
 - new mixing matrices (likely, since the scale of new physics it's not high)
 - in these models expect new particles with new flavor violation!

Flavor & New Physics

- Once we discover a new particle, its flavor and CP properties need to be investigated in production and decays
- There may be particles that can be primarily identified in a flavor (or lepton # or baryon #) violating (or at least non trivial) channel
- classic examples are RPV decays in SUSY or certain flavor gauge bosons - others??

Flavor & New Physics

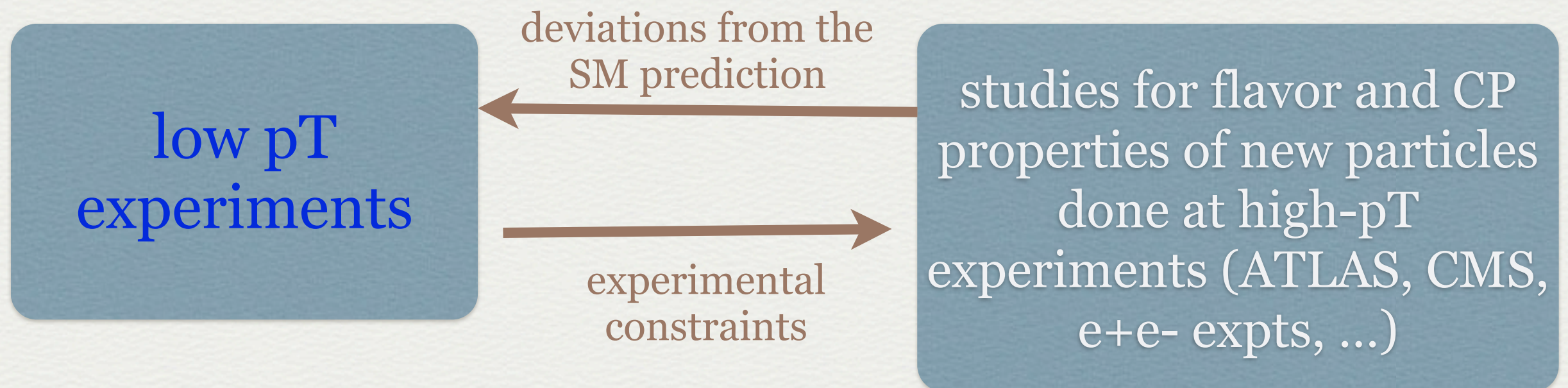
- some studies has been done in the past for certain models (SUSY, Randall-Sundrum, generic flavor gauge bosons, SUSY with RPV, ...)
- Need to study these question in well motivated models and scenarios but keeping an eye on covering the various topologies (tops vs flavor-tagged jets, e vs μ vs τ , ...)
- Need knowledge of jet flavor tagging and object reconstruction capabilities of future detectors

Flavor & New Physics

- New particles with flavor violating/non-universal couplings can also show up in low energy observables (bottom, charm, strange flavor and CP viol', low energy charged lepton flavor viol', EDM's, ...)
- One of the most interesting questions we need to ask is how much of what will be probed at high-pT in Flavor and CP observables is already covered/ will be covered by other experiments like LHCb and super-flavor factories

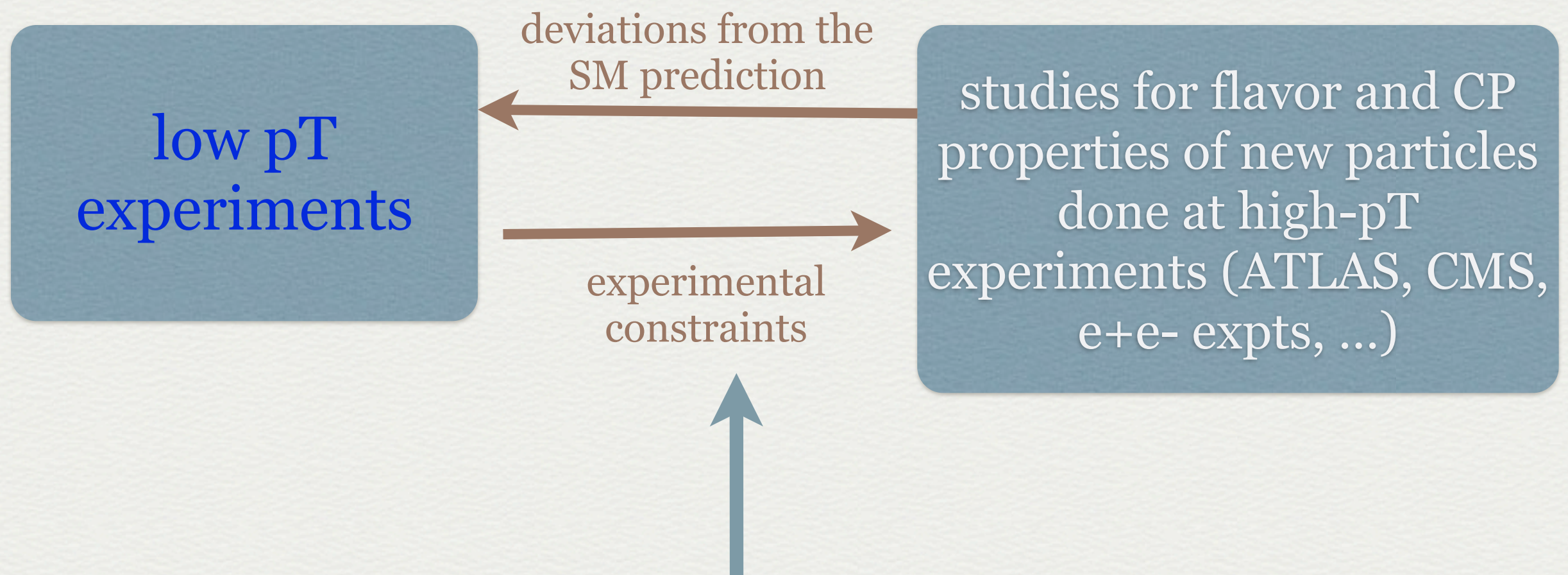
“high-pT” vs. “low-pT”

- High-pT studies need synergy with super-flavor factories / LHCb studies



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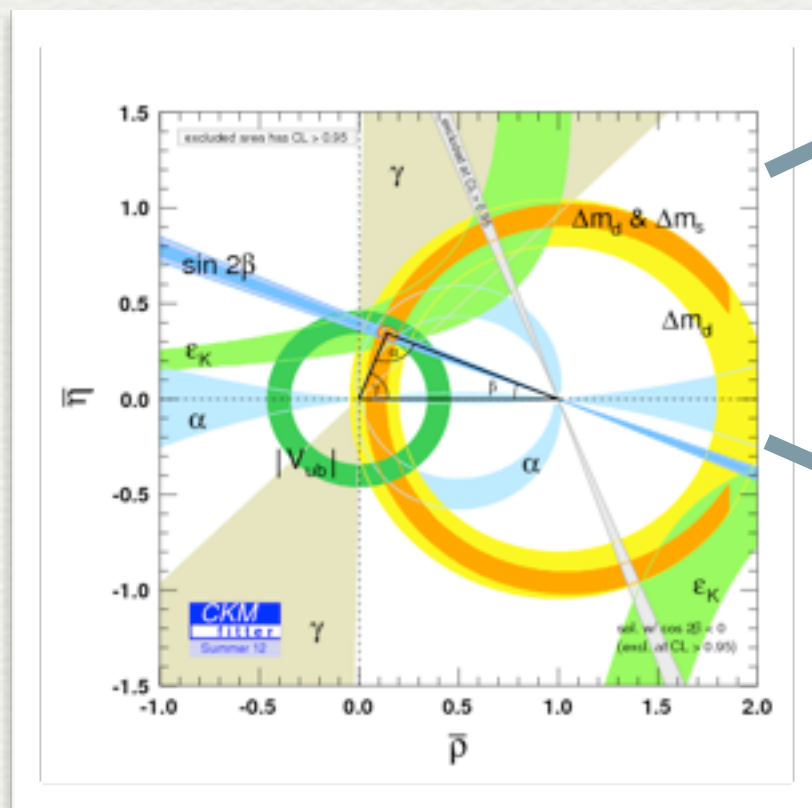
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No need to reinvent the wheel and look at the plethora of measurements, need a parameterization of the low pT results

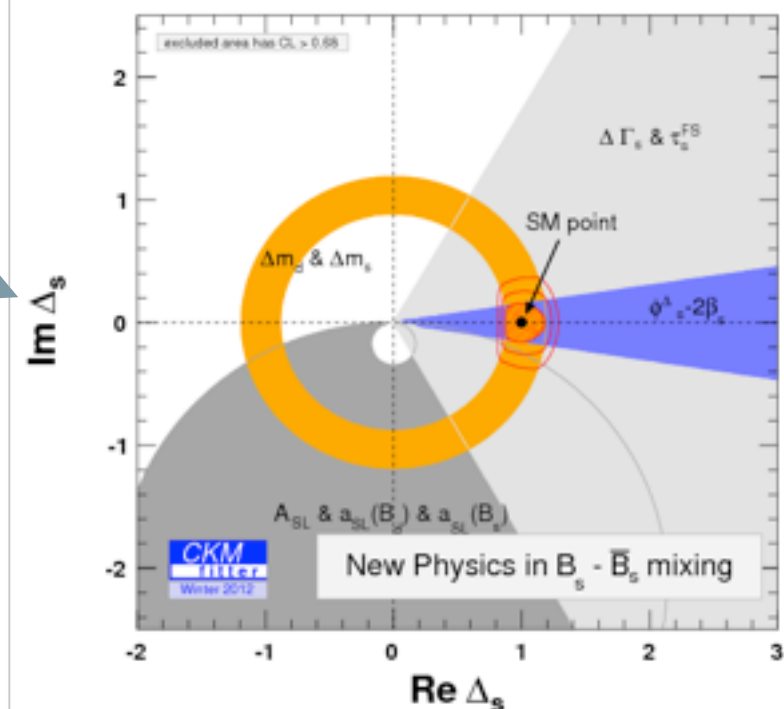
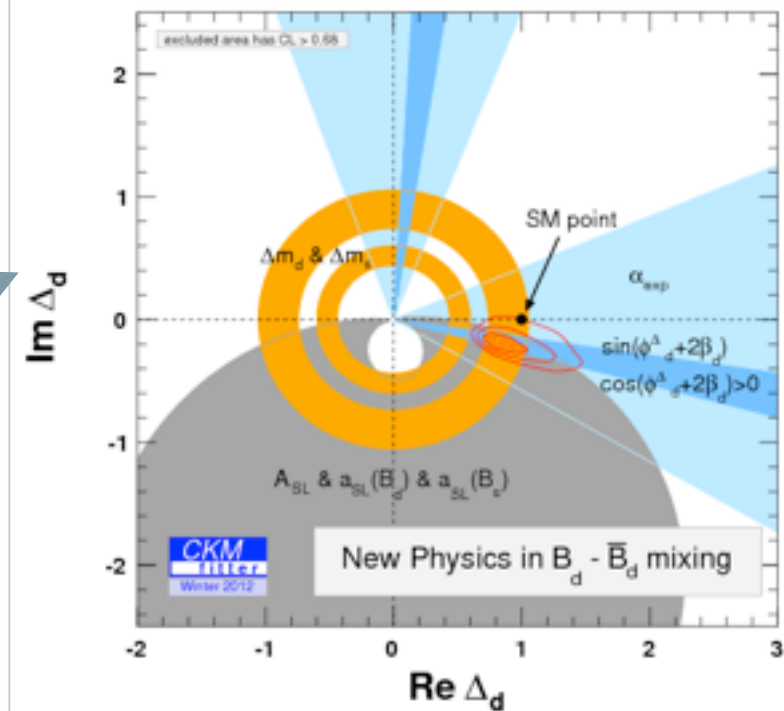
Flavor constraints

- $\Delta F = 2$ that language is well defined:



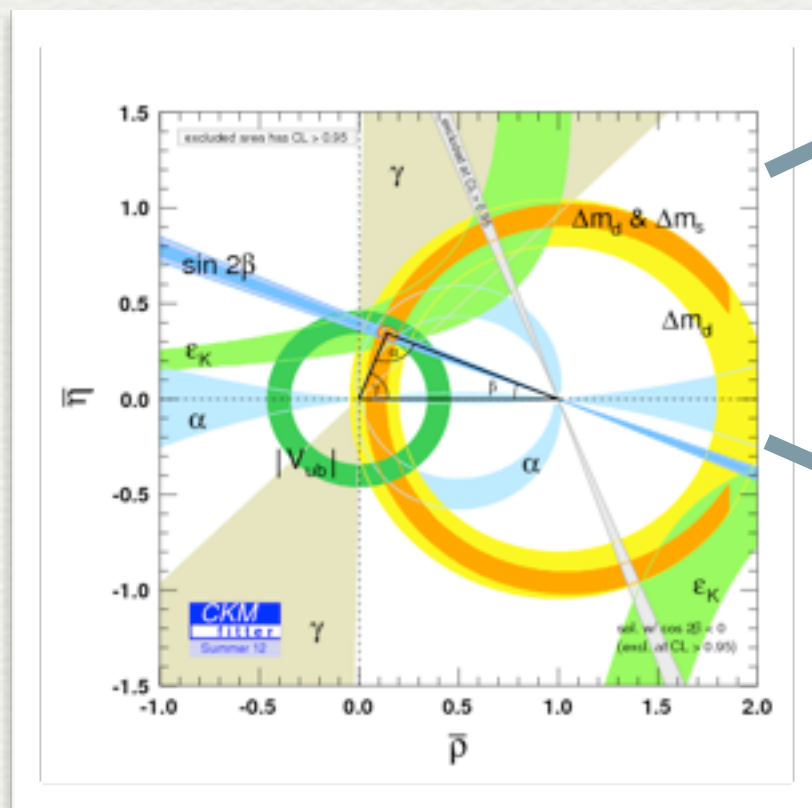
b-d

b-s



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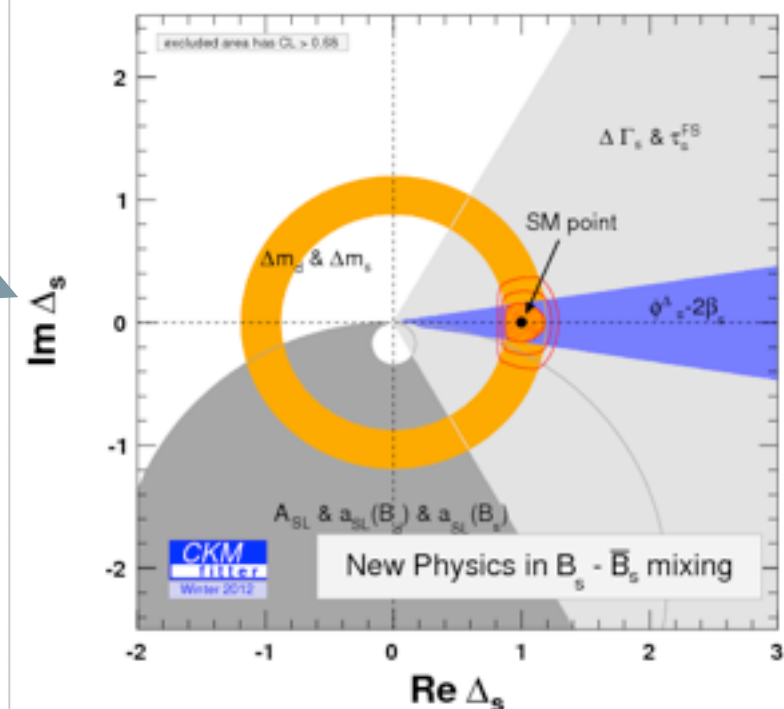
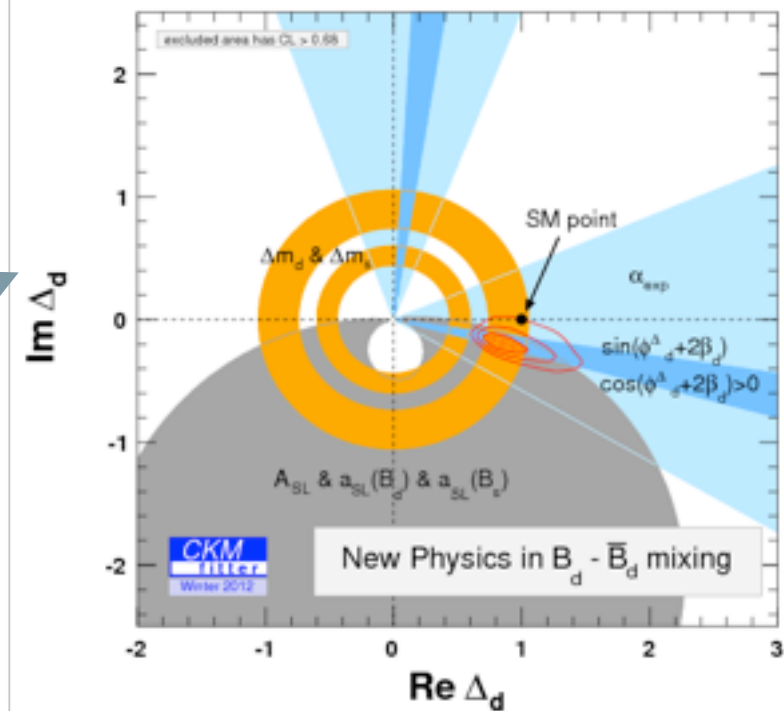
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b-d

b-s

Just need to compute the new physics contrib' and read it from a plot



Flavor constraints

- $\Delta F = 1$ “parameterizations” are not as formalized:
 - the most general param’ includes $C_1..C_{10}, C_{9V}, C_{10A}, C_{7\gamma}, C_{8g} + C \leftrightarrow C'$
 - not enough observables and not enough precision to do the general thing
 - for the future we will have new measurements and have precision measurements from LHCb & super flavor factories
 - What combination of parameters will be relevant? May depend on scenarios/models and observables that will be relevant. Need to work out these translations! (An experimental + theoretical question)
- synergy between IF Heavy Quark and HEF Flavor and CP groups

Pr

- Lot of the **work is out there**, but not with a view on the **future facilities** and current experimental results → need **update/improving/rethinking!!**
- Some of you have worked on these topics and we **hope** you'll **get involved** in this exercise
- We're planning to contact people after receiving feedback today and converge with them on models/scenarios to study in the next months
- There will be joint efforts with the Heavy Quark working group in the IF
- Our charges are available online @ <http://www.snowmass2013.org/tiki-index.php?page=Flavor+Mixing+and+CP+Violation+at+High+Energy>

Practicalities

- Planning to have top, Higgs flavor sessions in meetings organized by the top, Higgs groups
- Will try to manage the efforts with remote skype/evo meetings as much as we can
- Looking forward to your input/opinions today (in particular in the discussion session tonight)!!

Backup

Charges

- Charm, Bu and Bd, Bs and Bc and b baryons
 - What types of new CP violation physics are best seen in Bs, Bc and b baryons?
 - What is the role of rare decays in elucidating new physics?
 - Dilepton (N-lepton) final states $B_s \rightarrow \mu\mu, \tau\tau \dots$
 - Which observables in radiative decays/decays (e.g. $B_s \rightarrow \Phi \gamma$) and $(B(s) \rightarrow X l^+ l^-)$ are more sensitive to new physics?
 - What types of new CP violation physics B_u and B_d are best seen with a dedicated experiment at a hadron collider?
 - What new physics mass scales can be probed with flavour observables?
 - How do SM constraints (UT, CKM) impact models of NP?
 - Are there new observables that can elucidate the tensions in V_{ub} determinations?
 - What kind of new physics in charm decays can be discovered in future experiments at the energy frontier?
 - What is their expected sensitivity in light of the very high cross section for charm production and how do they compare with e^+e^- experiments?
 - What improvements in theory input are necessary to interpret the results?
 - future prospects and plans for lattice calculations of relevant matrix elements
 - the role of the penguins (e.g. assessing penguin pollutions on the various effective CPV angles).

Charges

- Top quark
 - What type of new physics models predict CP and/or Quark Flavor Violation (CPQFV) in the top sector?
 - What limits can be set on NP CPQFV models with top decays?
 - What measurement in top production/decay are most sensitive to NP?
 - How precisely do we need to measure V_{tb} ? Can we measure V_{ts} or even V_{td} directly?
 - How well can we measure FCNC in top decays ($t \rightarrow c, u$ ($\gamma/Z, l+l^-$))?
 - How well can we measure CPV in triple product correlations?
 - Are there other probes of new physics (e.g. forward-backward asymmetry)?
- Higgs
 - What type of new physics models predict CP and/or Flavor Violation in the Higgs sector?
 - What limits can be set on NP CP and/or FV models with Higgs decays?
 - What limits can be set on LFV in Higgs decay ($H \rightarrow \tau \mu, \tau e, \mu e$)?

Charges

- New heavy particles
 - What are the viable models of new physics at the TeV scale with Flavor non-Universality (beyond Yukawa couplings) and/or CP Violation and/or Quark and/or Lepton Flavor Violation specifically associated with new particles at the TeV scale? How can we test such models?
 - What are the more interesting lifetime ranges to explore in search of “invisible particles” messengers of the hidden sector (e.g. hidden valley particles).
 - What limits can be set on LFV heavy particles ($X \rightarrow \tau \mu$, τe , μe)?
- Leptons
 - Are there tau decays in which Lepton Flavor Violation (LFV) is best seen at a dedicated experiment at a hadron collider?
 - Are there models of lepton number violation at the TeV scale that can be tested at the next generation of accelerators?
 - Which mass ranges and couplings can be probed for Majorana neutrinos at high energy experiments?
- Baryons
 - Are there models of baryon number violation at the TeV scale that can be tested at the next generation of accelerators?